2003 NAE National Meeting Symposium in honor of Foreign Secretary Harold K. Forsen

Alternatives to Direct SNF Disposal: Advanced Nuclear Fuel Cycles

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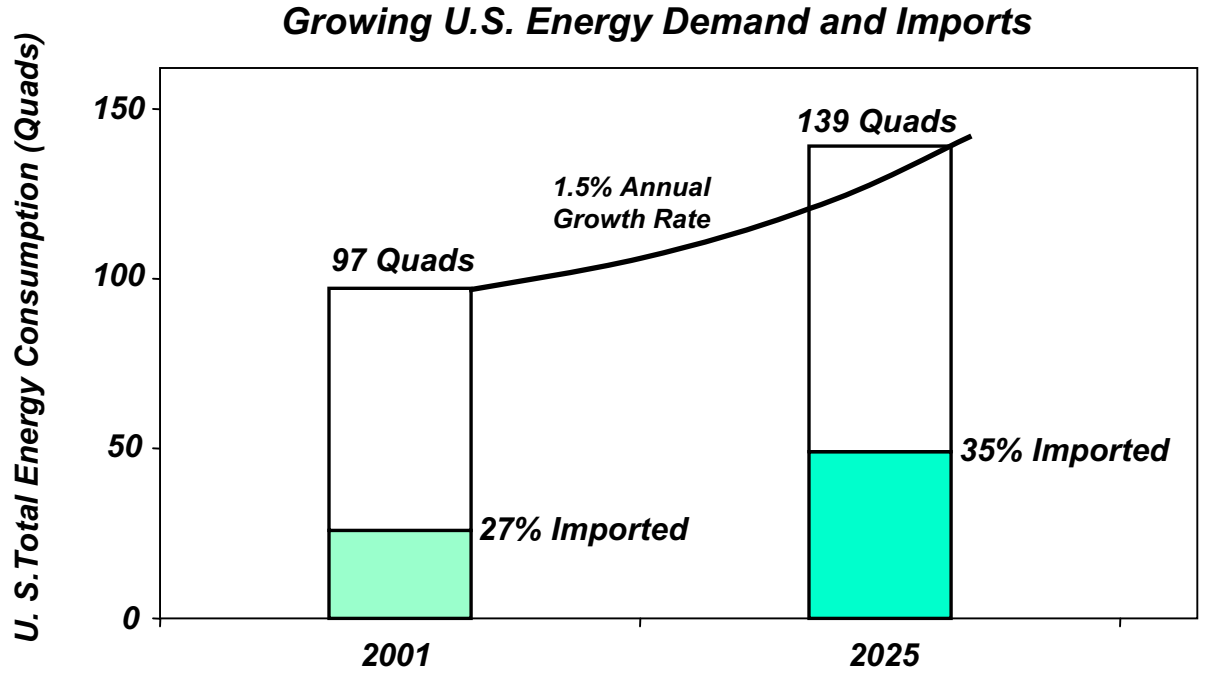
Outline

- *The Need for an Advanced Fuel Cycle in the U.S.*
- *Technology Options*
- *Program Outlook*

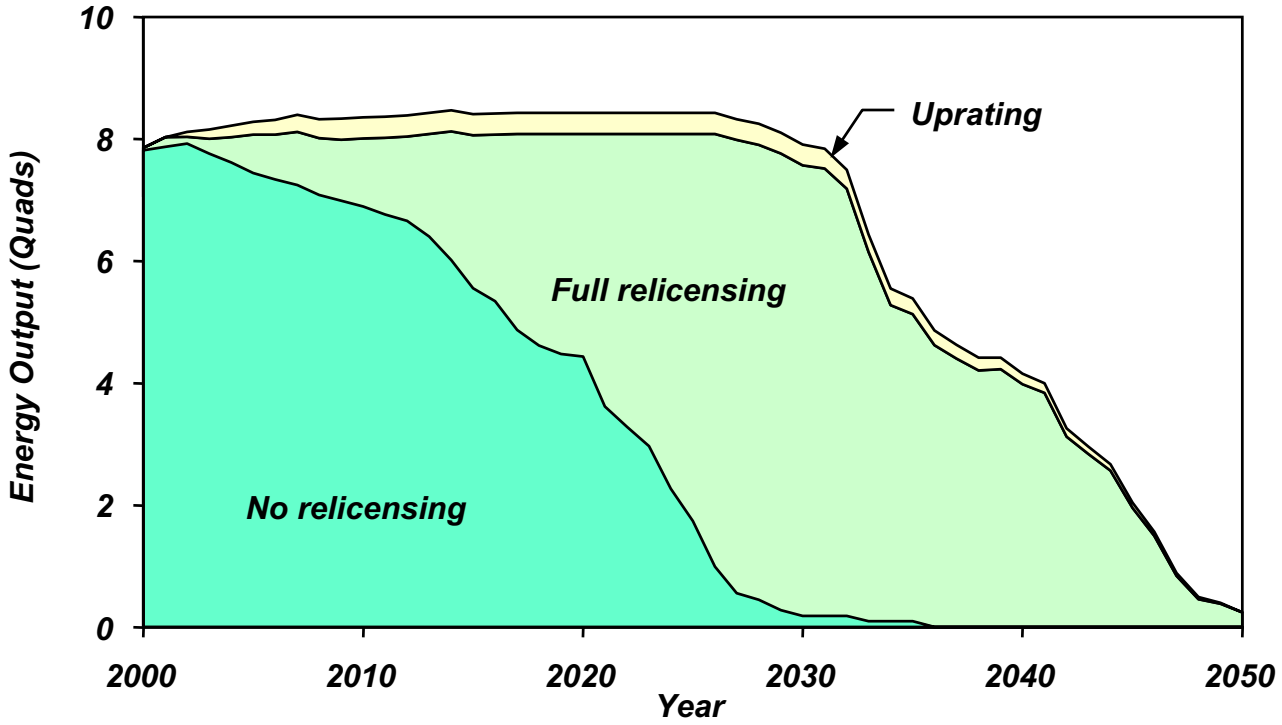
Forecast for Energy Growth



Source: 2003 Annual Energy Outlook

- Annual outlook is 1.5% growth in U.S. energy to 2025
- Most growth is in natural gas and coal
- Imports will increase
- Nuclear can contribute if deployed in the near-term, but waste will become a major issue for significant growth

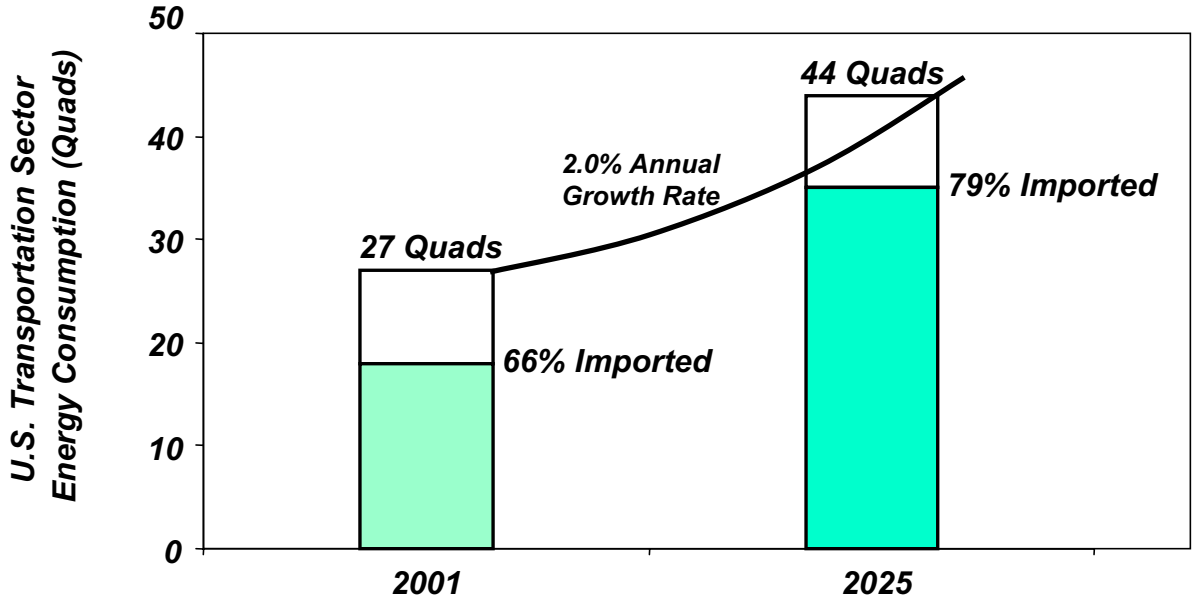
Nuclear Plant Extensions and Retirements



- *Many plants are successfully relicensing*
- *Nuclear growth is dependent upon new plants; ALWRs if they can be competitive in the U.S.*
- *Retirements would accelerate the need for deployment after 2030 to maintain the benefits of an increased share*

Potential for Nuclear in Transportation

Growing U. S. Transportation Sector Energy Demand and Imports



Source: 2003 Annual Energy Outlook

- Transportation sector growth leads electricity & heating
- Outlook is for a disproportionate increase in imports
- Increasing dependence on imports clouds the outlook for energy security and stability
- Hydrogen can contribute if production-distribution-end use issues can be successfully addressed

The Nuclear Hydrogen Outlook

- *President Bush has announced a FreedomFUEL program*
- *Long-term, a 30 million t/yr U.S. hydrogen supply would be able to serve one-quarter of our gasoline use*
- *Nuclear energy required for this would be 225 GWth*

The energy from one pound of nuclear fuel could provide the hydrogen equivalent of 250,000 gallons of gasoline without any carbon emissions.

"Within the scope of today's technology, nuclear fission is the only viable, clean source of large quantities of energy."

– Geoffrey Ballard
Founder, Ballard Power

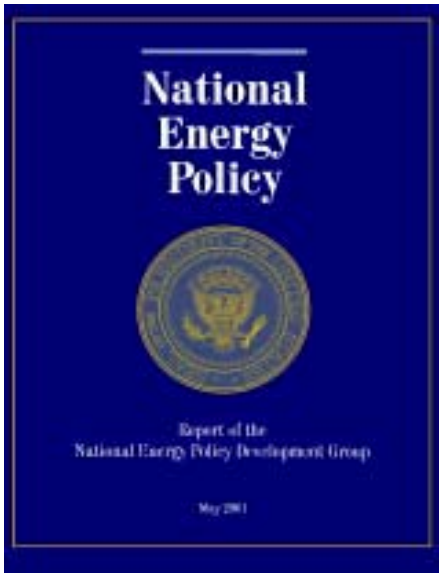
The National Energy Policy Recommends:

"The expansion of nuclear energy in the U.S.", and to

"Develop the next generation technology – including hydrogen," and that

"The U.S. should consider technologies…to develop reprocessing and fuel treatment…that are cleaner, more efficient, less waste-intensive, and more proliferation-resistant"

May, 2001



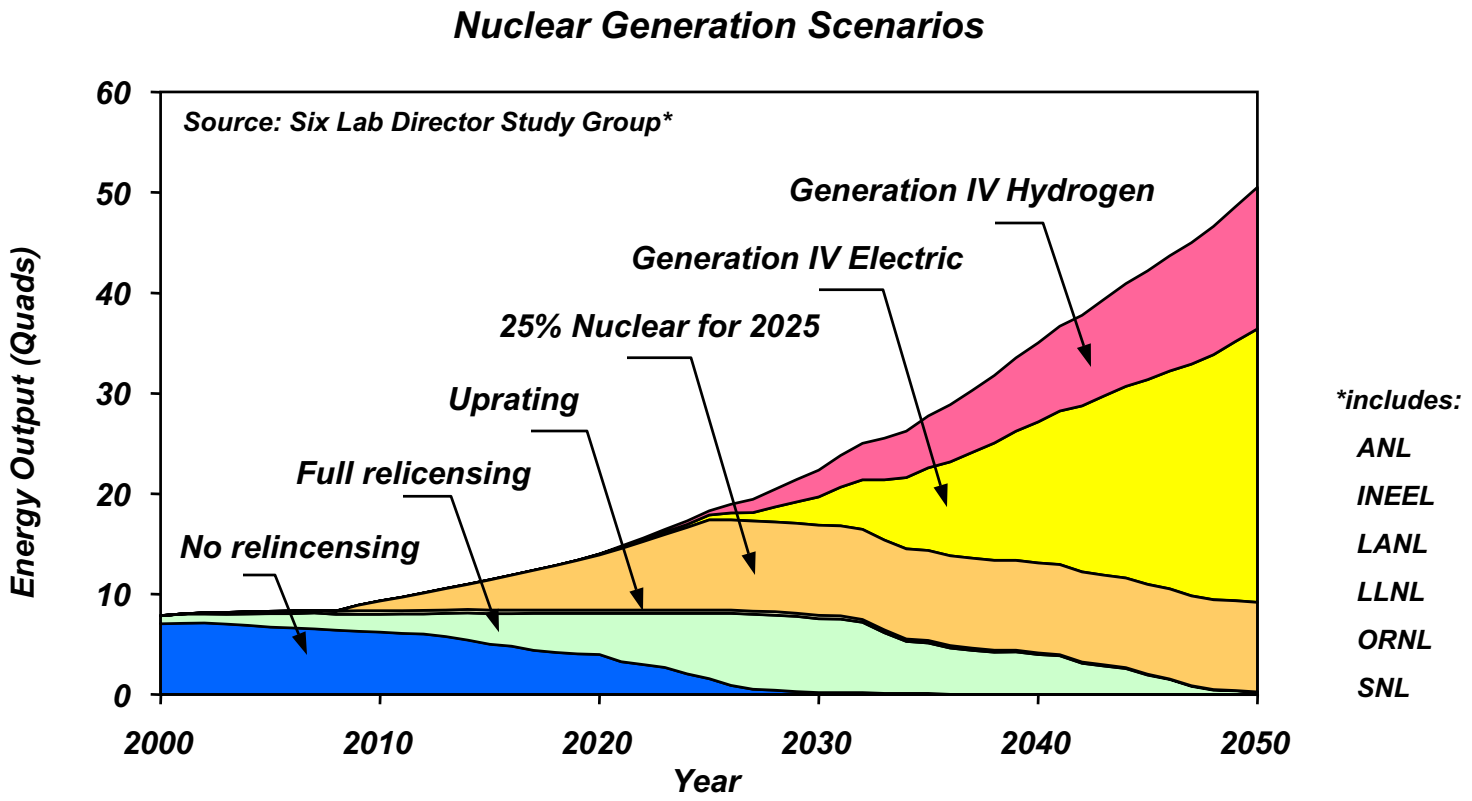
http://energy.gov/HQPress/releases01/maypr/national_energy_policy.pdf

– Vice President Cheney, and the Secretaries of State, Energy, Transportation, Interior, Commerce, Treasury and Agriculture, and heads of EPA and OMB, among others





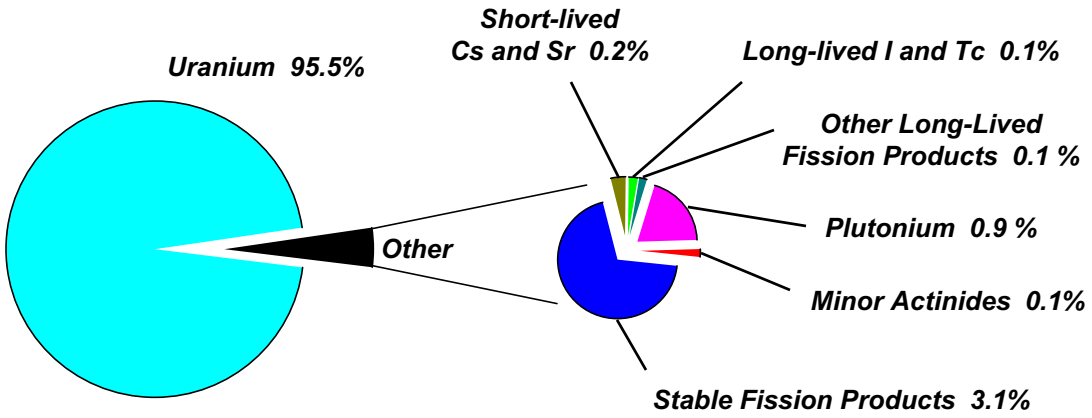
Expansion of the Nuclear Energy Supply



By 2050, with robust technology development:

- **50% of U.S. electricity production could be nuclear**
- **25% of U.S. transportation could use hydrogen from nuclear energy**

Constituents of Spent Nuclear Fuel



1 metric tonne of SNF contains:*

955.4 kg U
8.5 kg Pu (5.1 kg ^{239}Pu)

Minor actinides (MAs):

0.5 kg ^{237}Np
0.6 kg Am
0.02 kg Cm

Long-lived fission products (LLFPs):

0.2 kg ^{129}I
0.8 kg ^{99}Tc
0.7 kg ^{93}Zr
0.3 kg ^{135}Cs

Short-lived fission products (SLFPs):

1.0 kg ^{137}Cs
0.7 kg ^{90}Sr

Stable isotopes:

10.1 kg lanthanides
21.8 kg other stable

***33,000 MWD/MT, 10 yr cooling**

Partitioning SNF makes sense:

- ***Most is U and Pu, which can be usefully recycled***
- ***Most heat is produced by Cs and Sr, which decay in 300 yr***
- ***Most radiotoxicity is in long-lived fission products and the minor actinides, which can be transmuted and/or disposed in much smaller packages***

Advanced Fuel Cycle Initiative

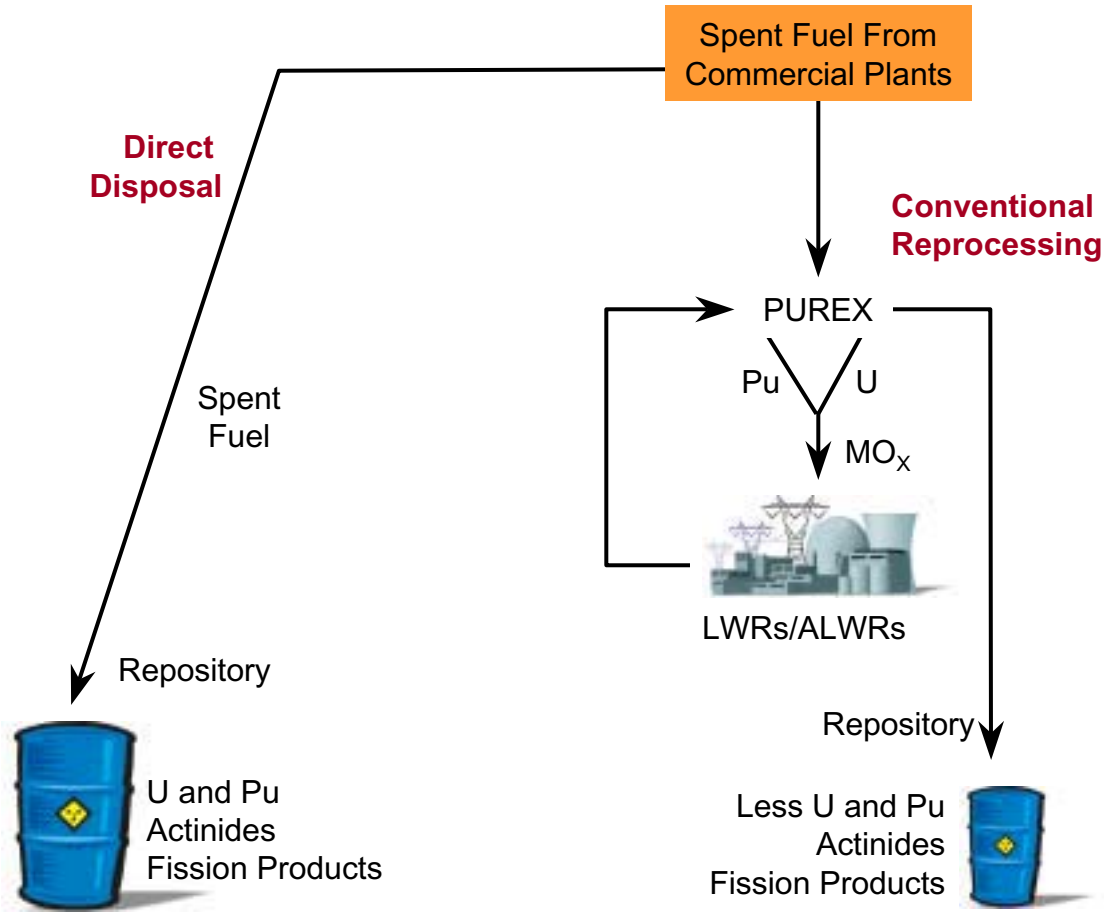
The goal of the DOE NE AFCI is to implement fuel cycle technology that:

- ***Enables recovery of the energy value from commercial spent nuclear fuel,***
- ***Reduces the cost of geologic disposal of commercial spent nuclear fuel,***
- ***Reduces the inventories of civilian plutonium in the U.S.,***
- ***Reduces the toxicity of high-level nuclear waste bound for geologic disposal, and***
- ***Enables more effective use of the currently proposed geologic repository so that it will serve the needs of the U.S. for the foreseeable future.***

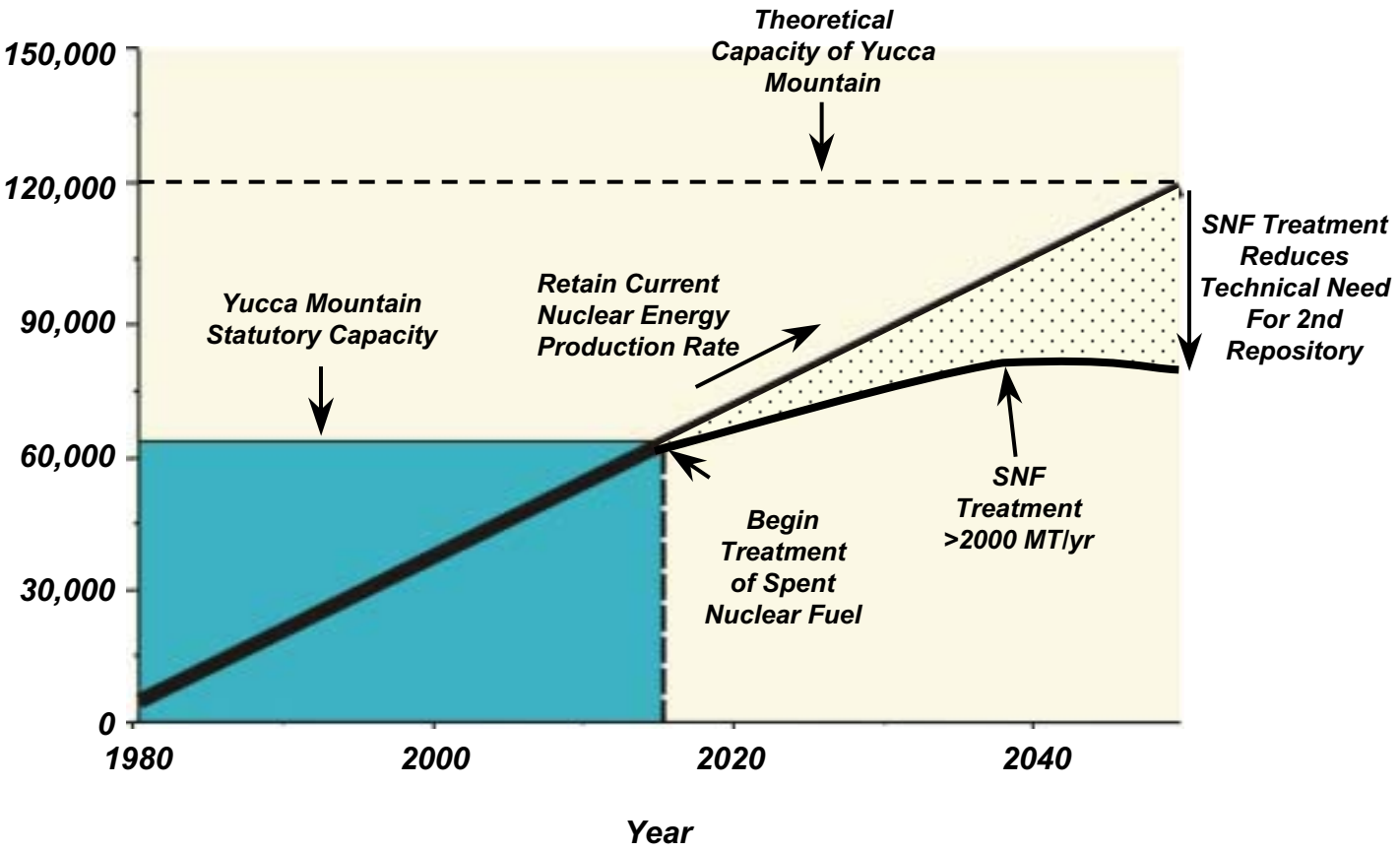
January, 2003

http://www.nuclear.gov/AFCI_RptCong2003.pdf

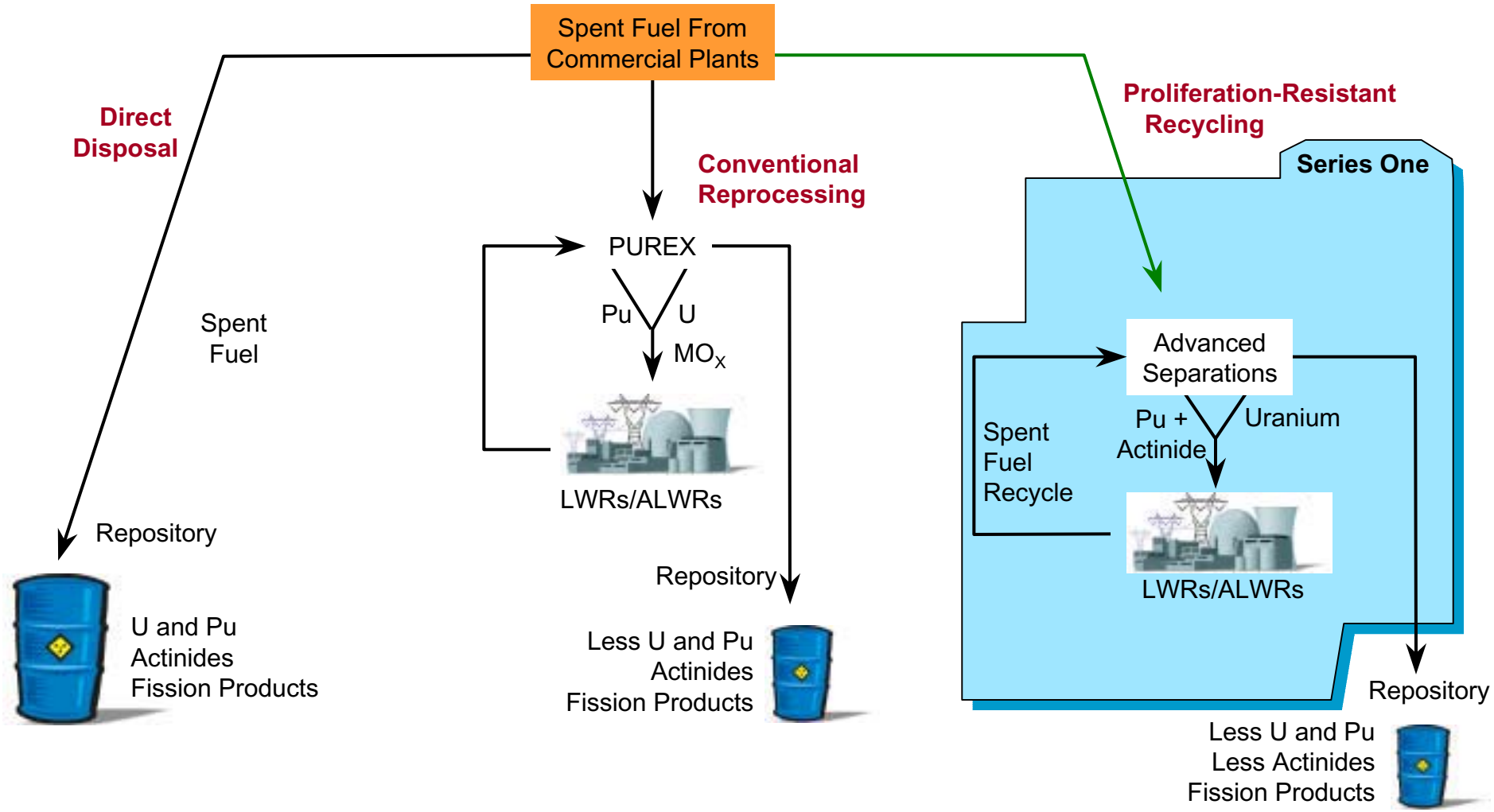
Current World Fuel Cycles



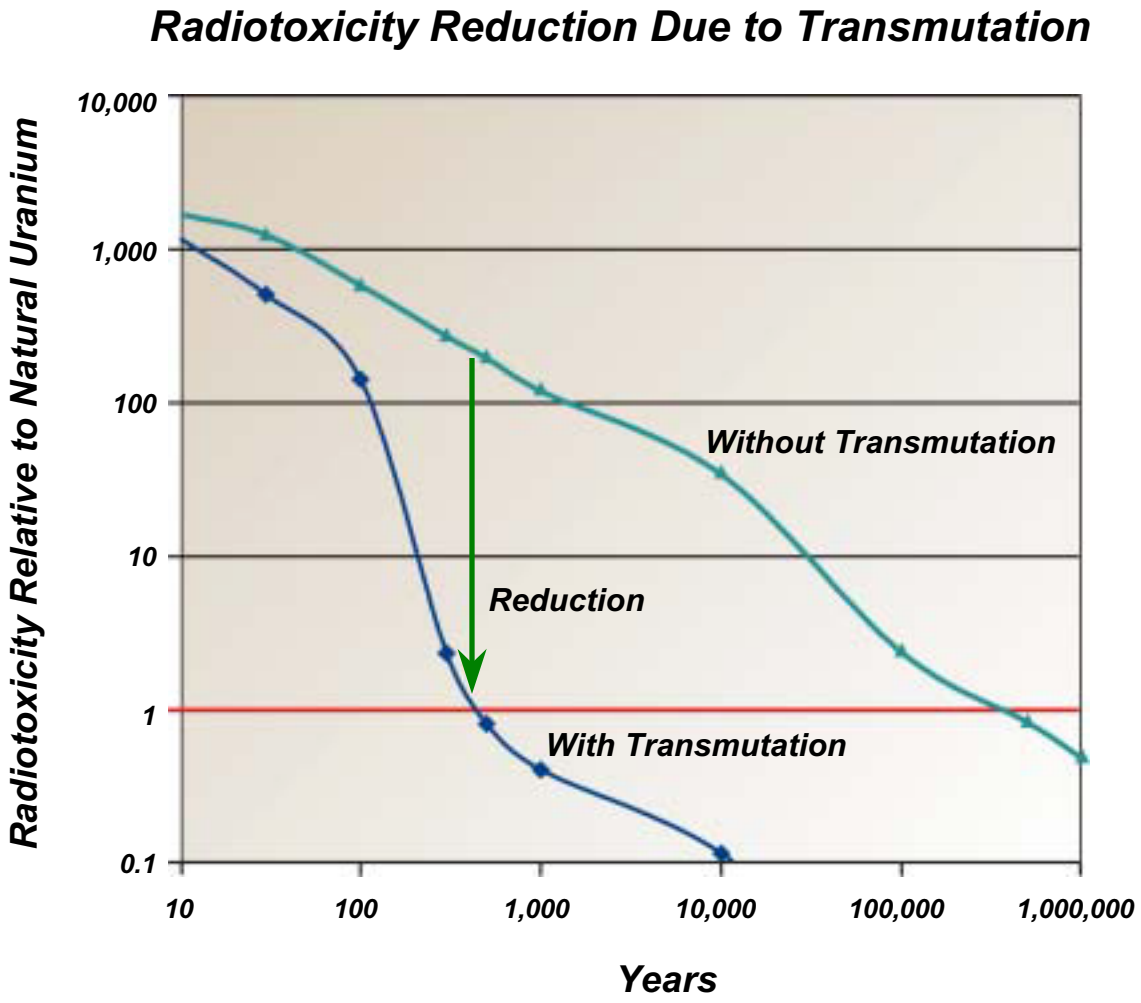
Benefit of Spent Nuclear Fuel Treatment



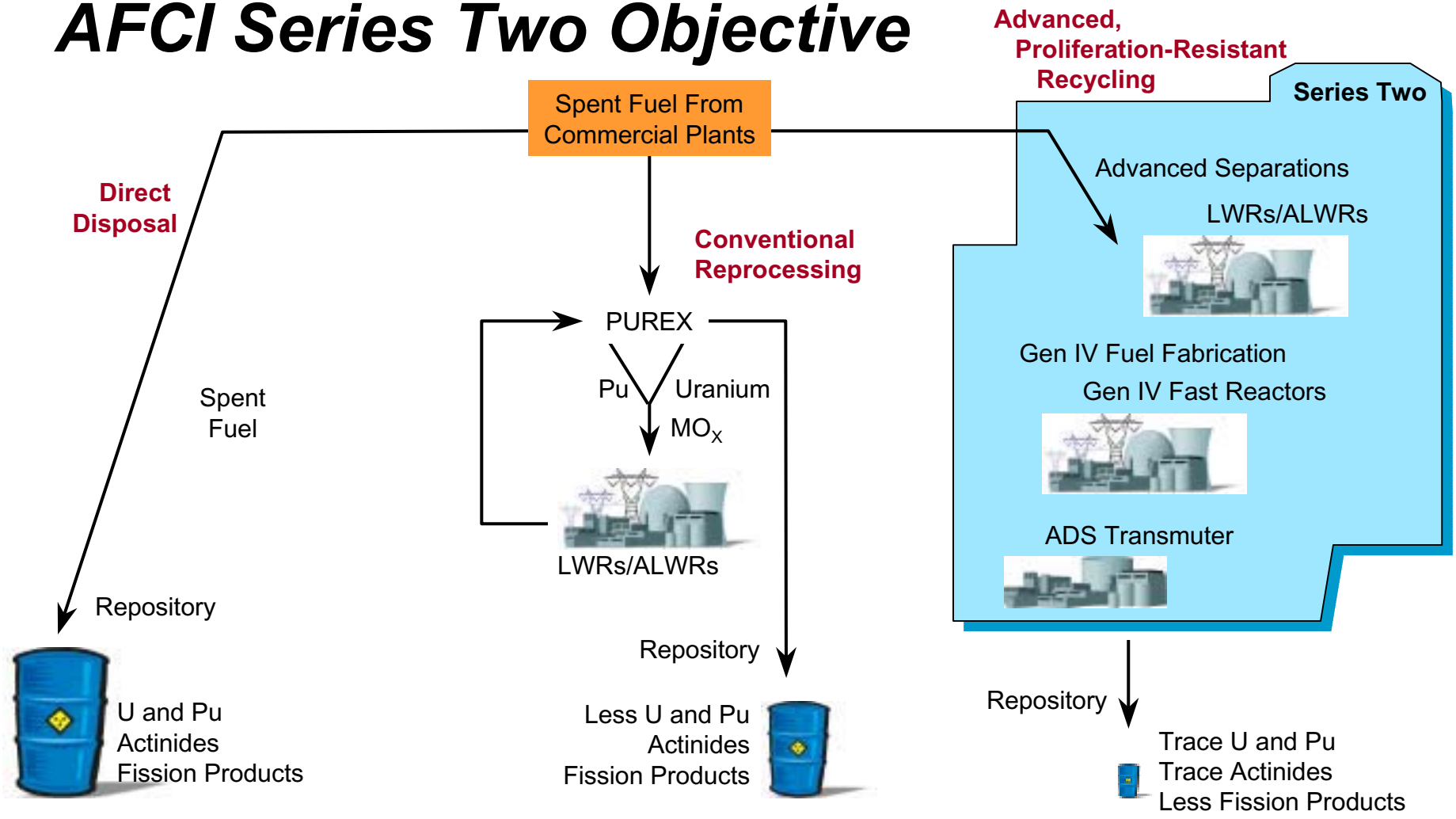
AFCI Series One Objective



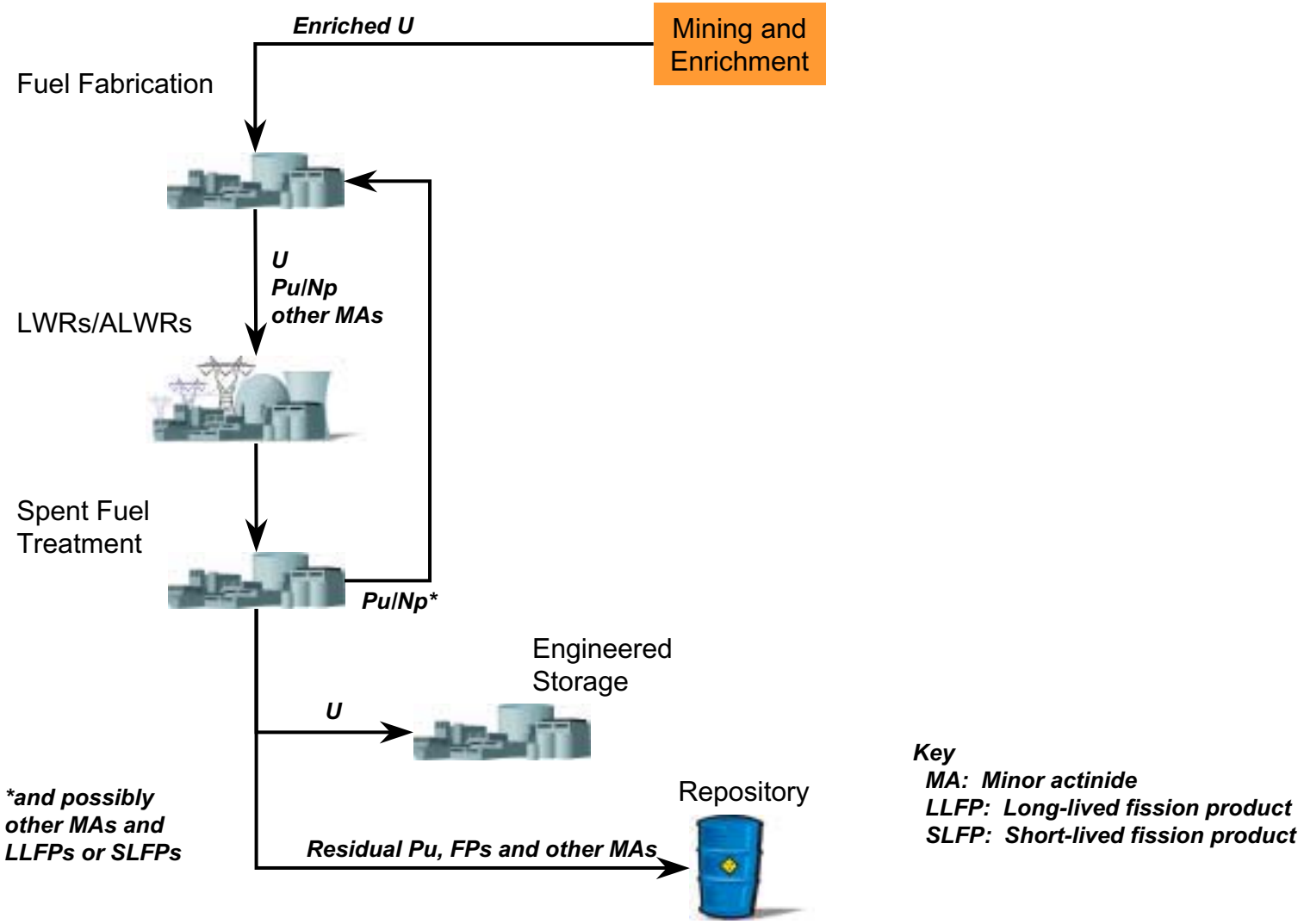
Benefit of Transmutation



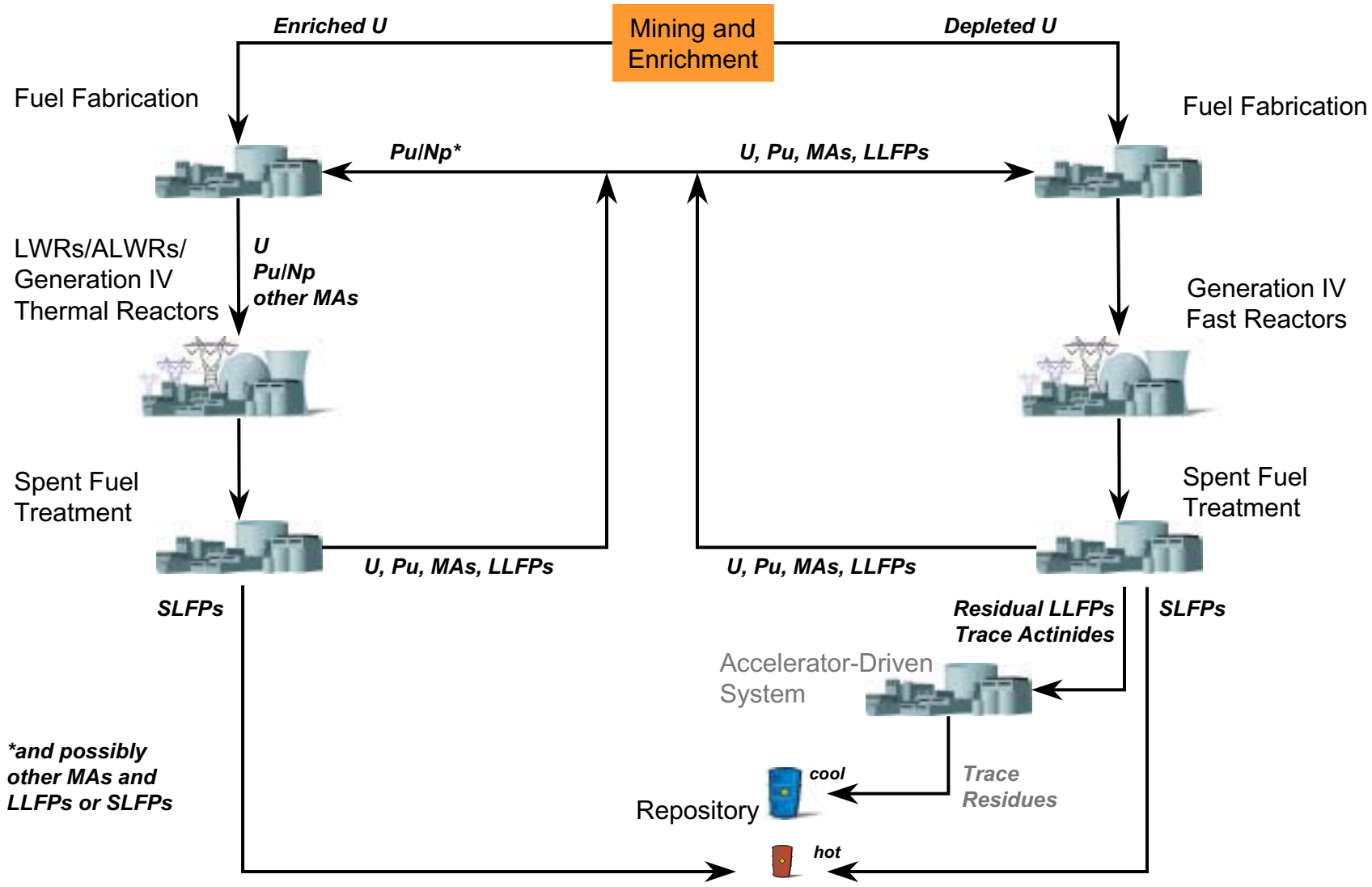
AFCI Series Two Objective



Fuel Cycle Options – Series One



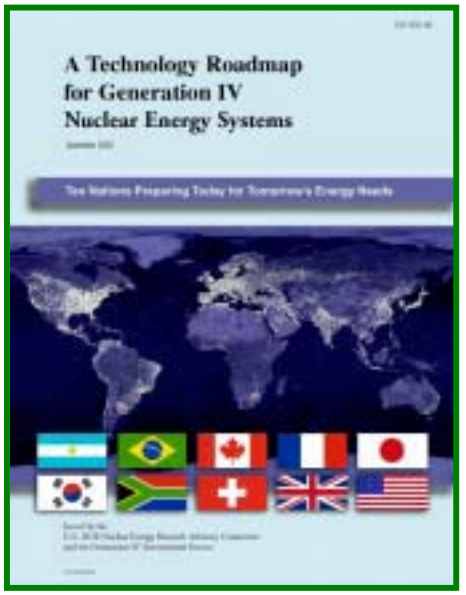
Fuel Cycle Options – Series Two



Generation IV Nuclear Energy Systems

- *Systems that are deployable by 2030 or earlier*
- *Six 'most promising' systems that offer significant advances towards:*
  - *Sustainability*
  - *Economics*
  - *Safety and reliability*
  - *Proliferation resistance and physical protection*
- *Summarizes R&D activities and priorities for the systems*
- *Lays the foundation for Generation IV R&D program plans*

December, 2002



http://nuclear.gov/nerac/FinalRoadmapforNERACReview.pdf

Generation IV International Forum (GIF)

Charter Approved

Jan 00 | Aug | Jan 01 | Mar | Jul | Oct | Jan 02 | Feb | May | Jul | Sep | Jan 03

Washington
- Initial meeting to discuss R&D interests

Seoul
- Drafted charter and technology goals

Paris
- Finalized charter
- Finalized goals
- Identified Roadmap participants

Miami
- Reviewed evaluation methodology and results to date

London
- Reviewed results to date
- Reviewed selection methodology

Paris
- Initial selection of six systems

Rio
- Finalized selection of six systems
- Reviewed R&D plans

Tokyo
- Identified R&D teams

U.S.A. | United Kingdom | Switzerland | South Korea | South Africa | Japan | France | Canada | Brazil | Argentina

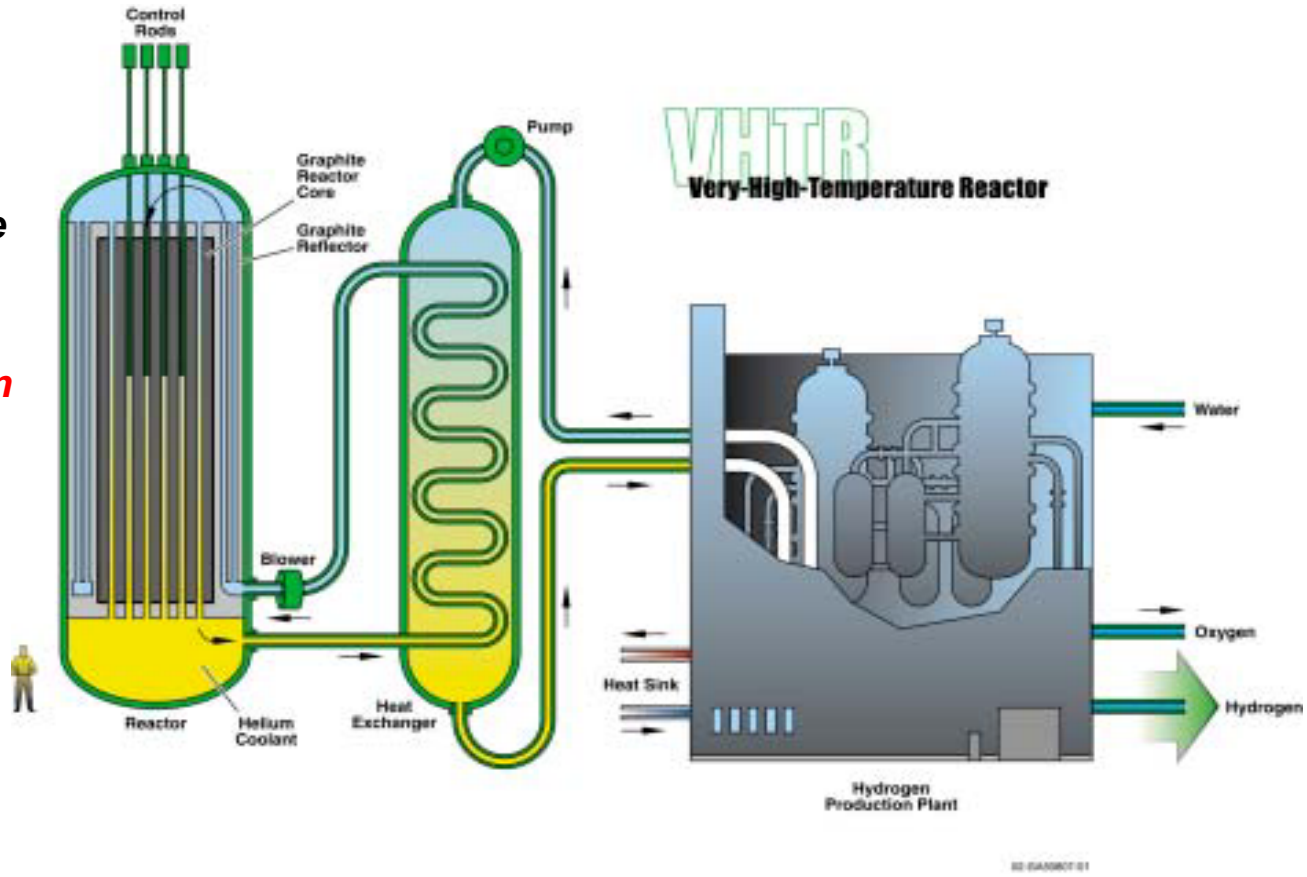
Very-High-Temperature Reactor (VHTR)

Characteristics

- ***Helium coolant***
- ***1000°C outlet temperature***
- ***600 MWth***
- ***Water-cracking cycle***

Key Benefit

- ***Hydrogen production***



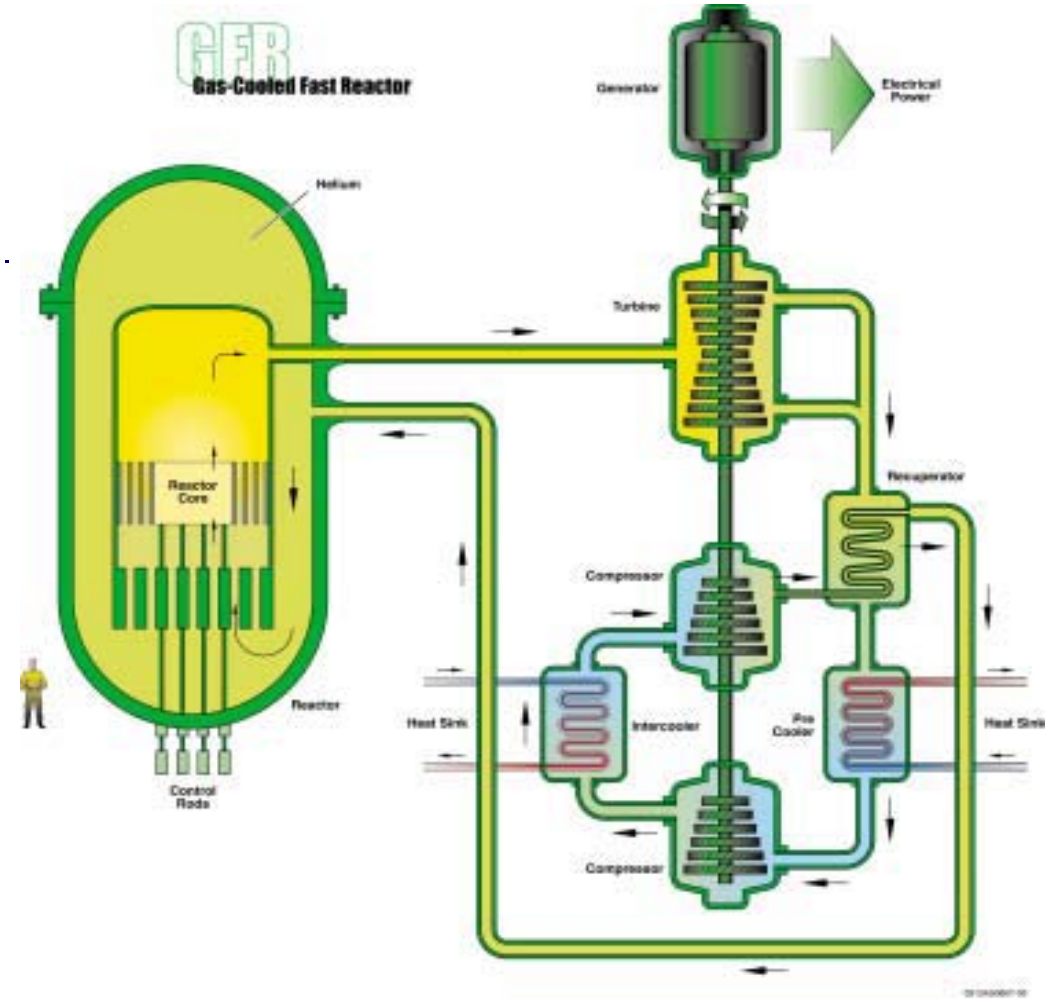
Gas-Cooled Fast Reactor (GFR)

Characteristics

- ***Helium coolant***
- ***850°C outlet temperature***
- ***Direct gas-turbine cycle***
- ***288 MWe***

Key Benefit

- ***Waste minimization and efficient use of uranium resources***



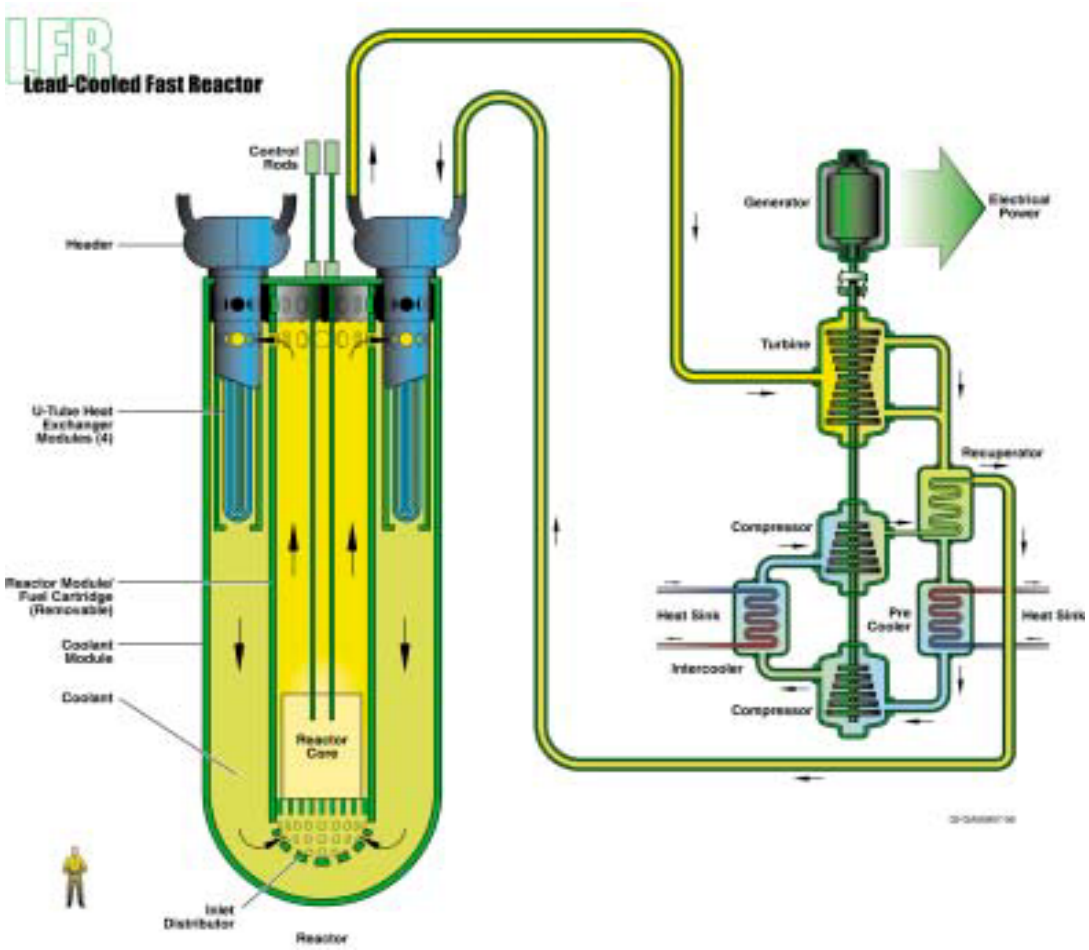
Lead-Cooled Fast Reactor (LFR)

Characteristics

- ***Pb or Pb/Bi coolant***
- ***550°C to 800°C outlet temperature***
- ***120–400 MWe***

Key Benefit

- ***Waste minimization and efficient use of uranium resources***



Summary

- *Expansion of nuclear energy will benefit energy security in both the electricity and transportation sectors of the U.S.*
- *Nuclear waste management will need to address expanding needs*
- *The DOE AFCI addresses transmutation with:*
  - *Technology advances to utilize the LWR/ALWR fleet*
  - *Technology advances to deploy with advanced fast reactors*
- *The DOE Generation IV program addresses next-generation nuclear energy systems for hydrogen, waste management and electricity*
- *International leadership is an important aspect of the programs*
- *These are long-term programs: many alternatives and options need to be explored*